will allow LMS systems to offer a wide variety of services to a necessarily expanded group of users. Expanded services and an expanded group of end users will enable LMS providers to spread threaten LMS systems as well as the use of Part 15 devices and radio amateurs.[47]

MobileVision shares the same concern that expanded LMS uses and end users could in the future create interference between the different services. However, as MobileVision noted above, expansion of the permissible uses for and users of LMS is necessary for the commercial viability of LMS. Furthermore, MobileVision respectfully submits that under the proposed rules Part 15 devices and amateur radio services should remain secondary to LMS systems and only be permitted to operate on a non-interference basis, as is the current situation.
To date MobileVision has only on a few occasions experienced interference from Part 15 devices and amateur radio operators. Under the current rules, Part 15 devices and amateur radio services are permitted use of the 902-928 MHz band on a secondary, non-interference basis only, and conversely they must accept interference from LMS systems.[48] The rules proposed by the Commission in this proceeding do not seek to change the status of Part 15 devices and radio amateurs. MobileVision believes that the proposed rules should continue to permit any Part 15 users and amateur radio services use of the 902-928 MHz only on a secondary, non-interference basis. While some commenters stated that the Commission should in this proceeding

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47 ADEMCO Comments at pp. 11-12; KNOGO Corp. Comments at p. 10; Part 15 Coalition Comments at p. 4 and American Radio Relay League Comments at pp. 11-12.

48 See 47 C.F.R. § 2.106, footnote US275 (1992) and 47 C.F.R. § 15.5 (1992).

take steps to protect Part 15 devices, elevate their status to a co-primary status or otherwise refine the Commission's policies towards Part 15 devices,[49] MobileVision believes that such steps are inappropriate and are beyond the scope of this proceeding.

MobileVision's understanding from the NPRM is that the Commission does not wish to consider relocating Part 15 devices and amateur radio services at this time, however, in the future, if alternative methods are not successful, Part 15 devices may choose to migrate over time to other portions of the spectrum.[50]

As to amateur radio operators, MobileVision proposes that all amateur radio operations be allowed only in the 902-928 MHz band within the 10 MHz authorized for narrowband transmissions. Essentially, radio amateur signals are narrowband, communications signals. Moreover, radio amateurs would pose a smaller interference threat to narrowband LMS systems than wideband LMS systems because narrowband LMS operations tend to be significantly more localized.

Regardless, any of these and other proposed alternatives for reducing interference from Part 15 devices and

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49 KNOGO Corp. Comments at p. 12; Spectralink Corporation Comments at p. 3; and Utilities Telecommunications Council Comments at p. 6.

50 Notice at ¶ 24 and Erratum at ¶ 3. Some commenters appear to have a different understanding. Several Part 15 commenters and radio amateurs seem to base their comments on the perception that the Commission presently is willing to consider relocation of Part 15 devices and amateur radio services. Utilities Telecommunications Council Comments at p. 4 and Jeffrey Ritter Comments at p. 1. Given this premise it is difficult to determine the level of concern expressed by the Part 15 commenters and radio amateurs.

radio amateurs may prove to be of limited success depending on the breadth of the proliferation of Part 15 devices and amateur operations. In this case, it may be necessary to eventually consider migrating or relocating Part 15 devices and amateur radio services to other frequencies.[51]

IV. THE COMMENTS SUPPORT ADOPTION OF THE COMMISSION'S PROPOSED TECHNICAL REQUIREMENTS, EXCEPT THE LIMITATION ON OUT OF BAND EMISSIONS.

A. Type Acceptance

Of the commenters that address the issue of type acceptance, all support the Commission's proposal to require type acceptance of LMS equipment.[52] While type acceptance is not a solution for co-channel interference between narrowband and wideband LMS systems and between wideband LMS systems, it does ensure compliance with other technical requirements.

Southwestern Bell, Location Services and Teletrac, while supporting the introduction of type acceptance, propose some type of grace period before which type acceptance would be required.[53] Southwestern Bell and Location Services propose a grace period of eighteen (18) months after the effective date of

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51 MobileVision notes that relocation or migration of Part 15 users and amateur radio services to the 2450-2483.5 MHz band is presently an option for both services if interference from LMS systems begins to significantly interfere with their operations.

52 See, for example, MobileVision Comments at p. 50 and Mark IV Comments at p. 13.

53 Southwestern Bell Comments at p. 23. Location Services Comments at p. 3 and Teletrac Comments at pp. 48-49.

the rules adopted in this proceeding. Teletrac proposes a one year grace period from the same date. MobileVision agrees that some reasonable period of time should be permitted before LMS providers are required to have their equipment type accepted and supports 18 months as an appropriate period.

B. Frequency Tolerances

Three of the five commenters that address the issue of frequency tolerances support the Commission's proposed frequency tolerances.[54] On the other hand, Hughes argues that the proposed frequency tolerances are too restrictive and Teletrac argues that proposed frequency tolerances should be more restrictive.[55] MobileVision continues to support the Commission's proposed tolerances.

C. Maximum Peak Effective Radiated Power

As stated in its Comments, MobileVision is unaware of any reason to reduce the maximum effective radiated power from the 500 watts permitted under the interim rules to 300 watts.[56]

Furthermore, MobileVision specifically opposes Amtech's proposal that the mobile units in wideband LMS systems limit the duration of their location pulses to 10 msec in any 100 msec period.[57] Amtech's proposal assumes frequency sharing among

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54 MobileVision Comments at p. 49; Mark IV Comments at p. 13; and Southwestern Bell Comments at p. 24.

55 Hughes Comments at p. 13 and Teletrac Comments at p. 49.

56 MobileVision Comments at pp. 49-50.

57 See Amtech Comments at p. 33.

wideband and narrowband LMS systems, more fully discussed above in Section II, and would place further burdensome restrictions on the operations of wideband LMS systems. Such an approach would impose such severe limitations on wideband LMS services as to render them useless. Only one commenter uses sub-millisecond because it allows a greater offering of services by LMS providers.

E. Out of Band Emissions

MobileVision continues to oppose the Commission's proposed method for measuring out of band emissions, as stated in its initial Comments.[60]

MobileVision believes that the first side lobes of the spread spectrum signal should be included in the allocated bandwidth because of the amount of energy that is contained in them, even after filtering. This is explained in Technical Annex 1 hereto. In its Comments, MobileVision suggested that the specification for "Transmitter Sideband Spectrum" should be 35 dB down from the peak of the signal at any frequency spaced from the center frequency by more than 50% of the authorized bandwidth, and 50 dB down from the peak of the signal at any frequency spaced from the center frequency by more than 100% of the authorized bandwidth.

This meant, in the case of a 2 MHz chipping rate, that the second and third side lobes should be at least 35 dB down, and the fourth and higher side lobes should be a least 50 dB down.

MobileVision considered this a reasonable specification but would even go further to suggest that the specification should be tightened to "45 dB down from the peak of the signal at any frequency spaced from the center frequency by more than 50%

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60 MobileVision Comments at p. 51.

of the authorized bandwidth." This is to ensure that the mobile transmitters have at least incorporated filtering to reduce out of band emissions and that adjacent systems, such as 1 MHz wide local-area systems, will experience as little interference as is possible.[61]

V. CONCLUSION

As set forth in its initial Comments, MobileVision supports the adoption of permanent rules in Part 90 governing the provision of location and monitoring services, in conjunction with ancillary communications services, to the public. Therefore, MobileVision urges the Commission to adopt the

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61 SBMS proposes limiting out of band emissions by, *i.e.*, 20 dB down on the first side lobe and a further 10 dB for each successive side lobe. If, as MobileVision argues, the out of band spectrum should be at least 45 dB down the peak, then the SBMS system actually requires 8 MHz.

proposals set forth in the Notice, consistent with MobileVision's initial Comments and those set forth in these Reply Comments, for the allocation of spectrum and the licensing and technical operations of LMS systems.

Respectfully submitted,

MOBILEVISION, L.P.

By [signature]
Marnie K. Sarver
John J. McDonnell
Matthew J. Harthun

REED SMITH SHAW & McCLAY
1200 18th Street, N.W.
Washington, D.C. 20036

Its Attorneys

July 29, 1993

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ANNEX 1
The PINPOINT "ARRAY" System - A critical analysis

1. INTRODUCTION

Based on the information provided in "The Operation & Characteristics of the Pinpoint ARRAY AVL System"(ref.1) provided as exhibit to the FCC Licence Application, plus Exhibit A of the "Comments of Pinpoint Communications Inc." PR. DOCKET NO. 93-61, RM 8013 (ref.2), a short analysis has been carried out to examine its characteristics.

2. RMS TIMING ERROR - ANALYSIS

2.1. RMS Timing Error Relationships.

In (ref.2) the rms timing error is shown to be:

$$\sigma_t^2 = \frac{1}{Bss^2 (S/N)_{out}} \tag{1}$$

where $1/Bss = Tr = 1$ chip duration

If M is the number of independent samples, then the variance of the average is:

$$\sigma_{ave}^2 = \frac{\sigma_t^2}{M} \tag{2}$$

Let the desired rms timing error be R. Then:

$$M = \frac{\sigma_t^2}{R^2} \tag{3}$$

Thus

$$M = \frac{1}{R^2 Bss^2 (S/N)_{out}} \tag{4}$$

Now the length of a pulse, $Tp = M.Ts$ where Ts is the duration of a single spread spectrum sequence.

Therefore $$Tp = \frac{Ts}{R^2 Bss^2 (S/N)_{out}} \tag{5}$$

Now $$Ts = L/Fc \tag{6}$$

where L is the length of the spreading code and Fc is the chipping rate.

and $$Bss = 1/Tr = Fc \tag{7}$$

therefore, $$Tp = \frac{L}{R^2 Fc^3 (S/N)_{out}} \tag{8}$$

Expression (8) above shows the relationship between the required length of the location burst, Tp, and the desired timing jitter on the TOA estimate. This is important because we are interested in the minimum length of a burst transmission in order to achieve as high a capacity as possible.

From this expression it appears that the duration of the location burst is inversely proportional to the cube of the chipping rate. This is true for a constant SNR but as the chipping rate is increased, the bandwidth is increased and thus the transmitted power must be increased in order to maintain the SNR.

Let us examine each term in the expression:-

2.2. Length of the spreading code, L

The longer the code, the longer the location burst. The longer the code, the fewer sequences in a given time, hence less averaging is possible. Thus, as far as capacity is concerned, it is desirable to have as short a code as practical. Short codes, however, equate to lower processing gain (PG) and small a jamming margin. This is shown as follows:

Now, $$(S/N)_{out} = PG(S/N)_{in} \tag{9}$$

thus $$(S/N)_{in} = \frac{(S/N)_{out}}{PG} \tag{10}$$

but, from (6) and (7) $$PG = BssTs = L \tag{11}$$

therefore, $$(S/N)_{in} = \frac{(S/N)_{out}}{L} \tag{12}$$

Expression(12) has assumed that the PG is equal to L. This is true for the correlation of each code sequence as is required for the determination of TOA. It is also true if the data encoded into the PN sequence is one data symbol per sequence, but if more data bits per sequence are encoded, then the effective PG for the reception of the data is decreased. For example, Pinpoint stated, in ref. 1, that they are encoding 4 bits of data into each 63 chip sequence. In ref. 2 they state that the data rate is 180kbps which indicates that they are encoding 2 bits of data into each 63 chip sequence. Therefore, the PG reduces from 63 toeither 63/4 = 12dB or 63/2 = 15dB, not 18dB,

From expression (12) it can be seen that the required input SNR is related to the inverse of the code length. Therefore, as the code length is reduced, the higher the required input SNR. For a code length of 255, and a required output SNR of 10dB (see para. 2.3), the required input SNR is 10.log(10/255) = -14dB This means that the power of any interfering or jamming signal, within the spread bandwidth, spread spectrum or narrow band, needs to be 14dB higher than the wanted in order to desensitize the wanted signal. This value of 14dB is known as the **Jamming Margin (JM)** and is more often seen in the following familiar expression of:

$$JM(dBs) = 10.\log PG - (S/N)_{out}(dBs) \qquad (13)$$

For a system with a PG of 12dB, the JM is only 2dB. This represents a very fragile system.

The Jamming Margin can be expressed as:

$$\frac{\Pr j}{\Pr} = \frac{PG}{(S/N)_{out}} \quad \text{where Prj is the power of the received jamming signal} \qquad (14)$$

As will be shown in section 4, the received signal strength is related to the distance[1] by $\Pr = (1/D)^{3.5}$

Hence $$\frac{PG}{(S/N)_{out}} = \frac{D^{3.5}}{D_j^{3.5}} \qquad (15)$$

Therefore $$\frac{D_j}{D} = \sqrt[3.5]{\frac{PG}{(S/N)_{out}}} = NFR \quad \text{(this is known as the Near-Far Ratio)} \qquad (16)$$

[1]Masaharu Hata, "Empirical Formula for Propagation Loss in Land Mobile Services", IEEE Trans. on Veh. Tech Vol VT-29, No.3 1980)

2.3. Output SNR

The output bit error rate (BER) is related to the output SNR. In order to achieve a desired BER, therefore, it is necessary to realise a particular SNR. BPSK, QPSK and MSK all have the same BER versus SNR characteristics and theoretically for a BER of 1 in 1000, a SNR of 7dB is required. Filtering of the waveform, in order to reduce the sidelobes (see clause 3), reduces the sensitivity by 1-2dB, and implementation loss is in the order of 1-2dB. Hence, the required output SNR, assuming proper error correction, is in the order of 10dB.

2.4. Chipping Rate Fc

From (8) it can be seen that the time of the required location burst is proportional to the reciprical of the chipping rate cubed. Thus, for twice the chipping rate, it appears that the length of the location burst is decreased by a factor of 8. The faster the chipping rate, however, the wider the required bandwidth. The wider the bandwidth, in order to achieve the desired input SNR, for the same transmitted power, it will be necessary to increase the PG, i.e. increase L the length of the spreading code sequence. Thus if the chipping rate is doubled, the length of the burst is decreased by a factor of 4, not 8. The following shows this:

From (10) and (11)
$$(S/N)_{in} = \frac{(S/N)_{out}}{L} \tag{17}$$

Expression (8) can be rewritten as;
$$Tp = \frac{1}{R^2 Fc^3 (S/N)_{in}} \tag{18}$$

Now
$$(S/N)_{in} = \frac{\mathrm{Pr}}{No} \times \frac{1}{Bss} = \frac{\mathrm{Pr}}{No} \times \frac{1}{Fc} \tag{19}$$

where Pr is the received power and No is the noise power per unit bandwidth.

Therefore
$$Tp = \frac{1}{R^2 Fc^2 (\mathrm{Pr}/No)} \tag{20}$$

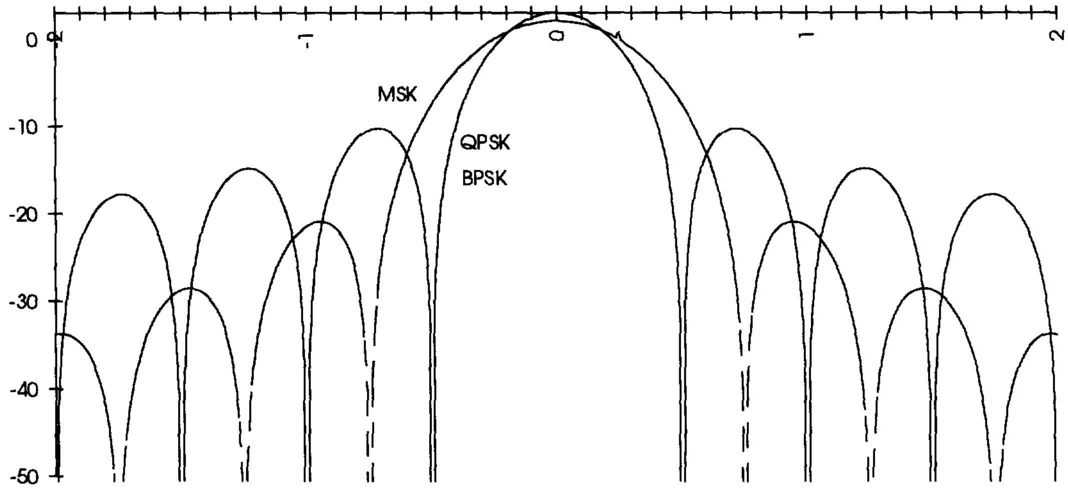
This is the better expression than (8) for comparing systems as it gives the time of the required location burst, for a desired timing jitter, for a constant received power i.e. for the same transmitted power. Expression (20) can be used to compare systems where the distance from the transmitter to the receiving site is the same, i.e. for equal cluster size. Given that the capacity of a system is dependent upon the area of a cluster, this is a better comparison.

3. BANDWIDTH

Expression (20) shows that the system capacity is proportional to $(1/Fc)^2$. A simple way, therefore, to increase the system capacity is to increase the chipping rate. The faster the chipping rate, however, the wider the bandwidth. The question as to what is the occupied bandwidth is now addressed.

The following discussion is based on extensive work and practical research carried out by METS, Inc. which confirmed the simulations and practical results as given by Morais and Feher[2],

The unfiltered power spectral densities of BPSK, QPSK and MSK consist of a main lobe and a series of side lobes as shown below.



Unfiltered BPSK, QPSK, MSK Spectra

In order to reduce the sidelobes of the spectrum, the data stream can be filtered. This filtering can dramatically reduce the energy in the sidelobes to about -40dB in the case of OQPSK and about -55dB in the case of MSK. With MSK the width of the main lobe is also reduced by filtering. The problem is that these waveforms are subject to limiting when amplified to the levels required. This limiting raises the level of the sidelobes, in both OQPSK and MSK to about -30dB. In the case of MSK the width of the

4. RANGE

In expression (12) we noted that the input SNR was inversely related to the PG or L, the length of the spreading code. The input SNR is related to the transmitted power and the transmission propagation or path loss. If the system requires a higher input SNR than another system, then, for equal transmission power, one system will have a farther range than the other.

In the Hata formula[3] the propagation loss due to distance is:

$(44.9 - 6.55 \log h_b) \log D$ where h_b is the base station antenna height (m) and D is the distance (kms.)

Thus for a 100ft (30m) mast, the distance loss is 35.22 log D and for a 300ft mast, the distance loss is 31.8 log D. Therefore, for a 100ft mast, the propagation loss is proportional to $D^{3.5}$.

Now
$$(S/N)_{in} = \frac{Pr}{N} \propto \frac{Pt}{N.D^{3.5}} \qquad (22)$$

where Pr and Pt are the received and transmitted powers respectively and N is the received noise power.

As $N \propto Bss$,
$$(S/N)_{in} \propto \frac{1}{Bss.D^{3.5}} \qquad (23)$$

Combining with (10)and (7)
$$(S/N)_{out} \propto \frac{PG}{Fc.D^{3.5}} \qquad (24)$$

Hence
$$D \propto \sqrt[3.5]{\frac{PG}{Fc}} \qquad (25)$$

Expression (25) shows that the shorter the code length the shorter the propagation distance, and the faster the chipping rate, the shorter the propagation distance.

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[3]The accepted formulas for the prediction of propagation loss in an urban environment are those in CCIR Recommendation 370-1 which are based on the Okumura prediction method (Y. Okumura et al., "Field strength and its variability in in UHF and VHF land mobile service",Rev. Elect. Commun. Lab., vol 16,1968). An empirical formula for propagation loss, derived from Okumura's report has been produced by Hata ("Empirical Formula for Propagation Loss in Land Mobile Services", IEEE Trans. on Veh. Tech., vol VT-29, No.3 1980). This formula has become standard in planning for land mobile systems.

To compare two systems, 1 and 2, therefore: $$\frac{D_1}{D_2} = \sqrt[3.5]{\frac{PG_1.Fc_2}{PG_2.Fc_1}} \qquad (26)$$

For example, for system 1, PG = L = 255 and Fc = 2Mchips/s
and system 2 PG = L = 63 and Fc = 5.687Mchips/sec

then, from (26) $$\frac{D_1}{D_2} = 2.02$$

This means that system 1 fundamentally has twice the range of system 2.

For the case where PG for system 2 is 63/2 i.e. 2 bits of data are encoded into each code sequence,

$$\frac{D_1}{D_2} = 2.46$$

This means that system 1 fundamentally has two and a half times the range of system 2.

5. SYSTEM COMPARISONS

5.1. System Values

The following values have been assumed in order to compare two systems. System A values are based on the declared characteristics of the Pinpoint system.

	System A	System B
L	= 63	= 255
Fc	= 5.768Mc/s,	= 2Mc/s
Data Rate	= 180kb/s[4]	= 7843b/s
PG	= 15dB	= 24dB
SNRo	= 10dB	= 10dB

5.2. Basic System Characteristic Comparisons

	System A	System B	Expression Used
Length of Burst,Tp, comparison	1:97.7		(8) (equal SNRo)
Length of Burst,Tp, comparison	1:8.31		(20) (equal Pr)
Jamming Margin, JM	5dB	14dB	(13)
Near-Far Ratio	1.39	2.51	(16)
Near-Far Ratio,NFR, comparison	1:1.8		
Occupied Bandwidth	23MHz	8MHz	(21)
Range comparison	1:2.46		(26)

[4] see footnote 5 overleaf.

6. DISCUSSION

6.1 Capacity

From the comparison table in para. 5.2, it can be seen that the Pinpoint system can legitimately claim a theoretical 8.31 times increase in system capacity over systems such as Teletrac and MobileVision, as a direct result of the use of a high chipping rate. The claims of 100 times the capacity are based on the expression (8) and on the assumption of an equal output SNR. But, as shown by expression (20), if the transmitted power is assumed to be equal for all the systems, and for equal cluster areas, then the improvement is seemingly 8.31 times.

Let us examine the consequences of using the high chipping rate and the short chipping code in order to practically realize this extra capacity.

6.2. Jamming Margin

The Pinpoint Jamming Margin is only 2 or 5dB, depending upon the actual Pinpoint data rate [5]. The MobileVision Jamming Margin is 14dB and extensive trials in the field have shown that, even at this level, problems with noise and intereference have been experienced. A Jamming Margin of 2dB represents an unusable system. The near-far ratio of only 1.14 represents a very poor figure and one which will certainly be susceptable to any form of interference. Thus it is not surprising that the data rate

8. CONCLUSIONS

The Pinpoint system claims appear to be based solely upon the expression (8). They have put in a set of figures into (8) so as to give the theoretical highest capacity without a clear understanding of the consequences. The resulting Jamming Margin and range, plus the required bandwidth, combine to give the conclusion that the Pinpoint system is totally impractical. It has low resistance to interference, it requires 23MHz of bandwidth and has poor range.

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ANNEX 2
The SBMS "QUIKTRAK" System - A critical analysis

1. INTRODUCTION

SouthWestern Bell, Mobile Systems proposes to use the Quiktrak system, which was developed in Australia. This system uses a novel approach in that it utilizes the frequency separation of the spectral lines of the spread spectrum to fit a number of frequency channels. The Australian system was developed for use in the 400MHz band.

2. ANALYSIS OF THE QUIKTRAK PARAMETERS

2.1. Basic System Parameters

The Australian Quiktrak system has the following parameters:

Frequency	= 420MHz
Chip Rate, Pc	= 1MHz
Code Length, L	= 511 chips
Code Repetition Rate, Pc/L	= 2000Hz
No. of frequency channels	= 12

The reason for twelve channels is based on the following:

At 400MHz, and vehicle speeds up to 100km/h, the doppler frequency allowance is ∓40Hz.{= f(v/c)}
For frequency accuracy of 0.1ppm, the frequency uncertainty is ∓40Hz.
Therefore, the total frequency tolerance is 160Hz.
With 511 code length and 1MHz chipping rate, the spectral lines are about 2000Hz apart, therefore 2000/160 = 12 frequency channels can be used.

At 900MHz both the doppler and frequency allowances more than double to ∓85Hz and ∓90Hz respectively, giving a total frequency tolerance of 350Hz. Thus, in the 900MHz band only 5 channels can be accommodated. It is further understood that one channel is used for the timing reference signal, thus the number of general purpose channels is 4.

2.2. Capacity

In Annex 1, the rms timing error is given as:

$$\sigma_t^2 = \frac{1}{Bss^2 (S/N)_{out}} \qquad (1)$$

where $1/Bss = 1chip = 1/Fc$

If M is the number of independent samples, then the variance of the average is:

$$\sigma_{ave}^2 = \frac{\sigma_t^2}{M} \qquad (2)$$

Let the desired rms timing error be R. Then:

$$M = \frac{\sigma_t^2}{R^2} \tag{3}$$

Thus $$M = \frac{1}{R^2 \, Fc^2 \, (S/N)_{out}} \tag{4}$$

Now $$M = \frac{Tp}{Ti} \tag{5}$$

where Tp is the length of the location burst
and Ti is the integration time for each sample.

In the other systems, MobileVision, Teletrac and Pinpoint, Ti is equal to Ts, the time of the code sequence, but in the Quiktrak system the use of narrow frequency channels means that the integration time is longer. This is explained as follows:

Let the number of channels be N. The channel spacing Cs is:

$$Cs = \frac{Fc}{L.N} \tag{6}$$

The maximum channel bandwidth is therefore Cs. In practice the channel bandwidth will need to be less than Cs so as to filter between the channels, therefore the integration time, Ti = k/Cs, where k is a constant.

Hence, $$M = \frac{Tp.Fc}{k.L.N} \tag{7}$$

Substituting in (4), $$Tp = \frac{k.L.N}{R^2 \, Fc^3 \, (S/N)_{out}} \tag{8}$$

Expression (8) shows that for a fixed output SNR the capacity of the system is proportional to the cube of the chipping rate. The output SNR is, however, dependent upon the bandwidth which is dependent upon the chipping rate, Fc. In Annex 1, the expression for Tp was derived based upon the received signal strength. The expression kLN is effectively the processing gain so the equivalent expression for the Quiktrak system is the same as derived in Annex 1, i.e.

$$Tp = \frac{1}{R^2 Fc^2 (\mathrm{Pr}/No)} \tag{8A}$$

Expression (8A) can be used to compare systems where the distance from the transmitter to the receiving site is the same, i.e. for equal cluster size. Given that the capacity of a system is dependent upon the area of a cluster, this is a better comparison.

From (8) we see that, for a particular output SNR, the location pulse needs to be kN times longer compared to a MobileVision type system. There are, however, N channels and therefore N simultaneous transmissions so that the capacity of the system is theoretically N/Tp locations per unit time in the case of Quiktrak and 1/Tp in the other cases.

From (8A) we see that for the case of equal received power, i.e. assuming equal transmission power and equal cluster size, the capacity of the Quiktrak system will be N times better than a MobileVision type system. Both the expressions (8) and (8A), however, need further expansion in the case of the Quiktrak system.

As stated previously the Quiktrak system uses frequency division with 5 channels spaced about 350 Hz apart. Let us assume that 2 signals are transmitted at the same time. As these transmissions could come from vehicles anywhere in the cluster area, at any particular receiving site the difference between the two could be in the order of 0 to 80dB. The receiver must therefore integrate the signal for a period long enough to separate out one signal, in the order of 100Hz[1] or less, separated from another signal that could be 80dB higher. This integration time is needed to separate out the desired signal and to allow the jamming margin to take effect. A full analysis of this problem is beyond the scope of this paper, but it is suggested that this time will be in the order of 15 times 1/100Hz, i.e. 150ms.

$$Tp' = \frac{kLN}{R^2 Fc^3 (S/N)_{out}} + \frac{3.5K}{Cs} \tag{8'}$$

where K = 10 -15

$$Tp' = \frac{1}{R^2 Fc^2 (\mathrm{Pr}/No)} + \frac{3.5K}{Cs} \tag{8A'}$$

In practice, therefore, the Quiktrak system has an overhead of about 150ms that has to be added to Tp i.e.Tp' = Tp + 150ms.

Because one channel is used for timing reference, the number of available channels is N-1.

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[1]Assuming a linear distribution of the frequency 0-350Hz, due to doppler and frequency accuracy, the variance is given by $350^2/12$, which gives a standard deviation of 100Hz.

2.3. Processing Gain

The Processing Gain PG is defined as follows:

$$PG = {}^{Bss}\!/_{Bm} \qquad (9)$$

and Bm is the message, or detected, bandwidth.

In the Quiktrak system Bm is effective channel bandwidth, kCs,
therefore, $$PG = kNL \qquad (10)$$

This effective increase in the PG is a main attraction of the Quiktrak system.

2.4. Jamming Margin

As shown in Annex 1 $$JM(dBs) = 10.\log PG - ({}^{S}\!/_{N}) \quad (dBs) \qquad (11)$$

2.6. Near-Far Ratio

In Annex 1, the Near-Far Ratio is shown to be

$$\frac{D_j}{D} = \sqrt[3.5]{\frac{PG}{(S/N)_{out}}} = NFR \tag{14}$$

Assuming System 1 is Quiktrak and System 2 a MobileVision type system, we get:

$$\frac{NFR_1}{NFR_2} = \sqrt[3.5]{\frac{kL_1.N}{L_2}.\frac{(S/N)_{out2}}{(S/N)_{out1}}} \tag{15}$$

2.7. Signal to Noise Ratio

In Annex 1 the output SNR was derived to be 10dB based on the BER requirements for BPSK/QPSK/MSK. In the Quiktrak system this figure is not so easy to derive as a relatively good signal to noise ratio is required in order to separate the channels. An analysis, based on the stated lengths of the location bursts, 1112ms and 278ms, and expressions given in this paper, indicate that the required output SNR is in the order of 16dB. This figure is used for comparison purposes.

2.8. Value of k